# Monitoring of Oiled Mussel Beds in Prince William Sound

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| Project Number: | 00090 |
| Restoration Category: | Monitoring |
| Proposer: | Patricia M. Harris and Christine C. Brodersen<br>NMFS, Auke Bay Laboratory<br>ABL Program Manager: Dr. Stan Rice<br>NOAA Program Manager: Bruce Wright |
| Lead Trustee Agency: | NOAA |
| Cooperating Agency: | ADF&G |
| Alaska Sea Life Center: | No |
| Duration: | closeout |
| Cost FY 00: | $ 64,000 |
| Geographic Area: | Prince William Sound |
| Injured Resource/Service: | Mussels, Intertidal Communities, Vertebrate predators ,Subsistence |


## ABSTRACT

This project assesses the recovery of 28 mussel beds in Prince William Sound that still had significant concentrations of *Exxon Valdez* oil when last sampled in 1995 or 1996. Continued sampling is warranted until impacted mussel predators are fully recovered or hydrocarbon concentrations in the sediments and mussels in the beds return to pre-spill levels. In 1999 we will measure hydrocarbon concentrations in mussels, other invertebrates, and sediments and monitor densities of mussels and other selected invertebrates in these beds. We replaced oiled with clean sediments in 12 of the beds in 1994. Replaced sediments remained clean though 1995 and mussel hydrocarbon concentrations decreased significantly. However, 1996 samples indicated recontamination of the replaced sediments and the potential for recontamination of mussels. Sampling in 16 beds that were not restored will document rates of natural recovery. To complete the design, we will sample mussels, sediments and other invertebrates in two unoiled reference beds. In 2000 we propose to complete the chemical analysis of samples collected in 1999, complete data analysis, and prepare final reports.

## INTRODUCTION

Many blue mussel (*Mytilus trossulus*) beds impacted by the *Exxon Valdez* oil spill (EVOS) were not cleaned by the EVOS Interagency Shoreline Cleanup Committee to minimize damage to the beds. Natural processes did not quickly reduce the substantial amounts of *Exxon Valdez* oil (EVO) remaining in mussels and sediments underlying mussel beds. In 1992, the Auke Bay Laboratory and National Park Service (Restoration Project R103) documented 50 mussel beds in Prince William Sound (PWS) and 9 on the Kenai and Alaska Peninsulas with underlying sediment concentrations greater than 1700 Fg/g total petroleum hydrocarbons (TPH) wet weight; 25 of the beds in PWS had concentrations in excess of 10,000 Fg/g TPH. The highest oil concentrations found in animals or sediments in 1991 and 1992 by any researchers in the *Exxon Valdez* spill area were in mussel beds and underlying sediments in PWS. Persistent high concentrations of hydrocarbons in mussels were identified as a possible source of impacts in several consumer species and could also impact human subsistence users.

Attempts to manipulate mussel beds to reduce hydrocarbon levels in 1992 and 1993 (projects R103-1 and 93036) were minimally intrusive and minimally effective. Small scale removal of strips of mussels to increase water circulation through the beds and thereby reduce hydrocarbon levels did not significantly lower hydrocarbon concentrations in sediments or mussels. Adult mussels from the surrounding bed recolonized exposed areas within three months, thus preventing further hydrocarbon flushing. Transplanting small patches of oiled mussels to nearby clean sediments reduced hydrocarbons in those mussels, but mussel mortality was high. (Babcock et al. 1998.). Overall hydrocarbon concentrations in the five manipulated beds remained high (Babcock et al.1996).

The scale of restoration was increased in 1994 (project 94090) at the request of Chenega Bay residents. We manually removed oiled mussels, replaced oiled sediments underlying the mussels with clean sediments, and replaced mussels onto the clean sediments in 12 of the most impacted mussel beds. Hydrocarbon levels in the clean replaced sediments remained low from late summer 1994 through early summer 1995, and total polyaromatic hydrocarbons (TPAH) in mussels were greatly reduced by 1995. However, in 1996 when restored beds were last sampled, TPH concentrations in sediments directly under the mussels ranged from 340 to 9000 mg/g, indicating recontamination in 6 of the 12 beds. Mussel densities showed overall decline in most restored beds from the fall of 1994 to summer 1995. Declines were also observed in reference beds and therefore were not necessarily linked to restoration (Babcock et al.1998.).

In most untreated beds, hydrocarbon concentrations in mussels and underlying sediments declined at variable rates. Environmental differences between sites as well as differences in the distribution and amount of subsurface oil affected the rate of decrease. In 1995, 16 sampled mussel beds in PWS remained oiled; TPH in sediments ranged up to 20,000 mg/g wet weight and TPAH in mussels ranged up to 4.5 mg/g dry weight. Significant natural reductions in hydrocarbon concentration were observed in roughly half of the beds surveyed. Concentrations should reach background levels within three decades of the spill in these beds. (Background concentrations are

defined as 50 ug/g TPH wet weight in sediments and 0.09 mg/g TPAH dry weight in mussels, based on minimum detection limits of analytical instruments and historical data from unoiled sites). The 16 untreated beds have not been sampled since 1995; three of them were still visibly oiled in the spring of 1997.

Hydrocarbon concentrations in other invertebrates in mussel beds have been undersampled, considering these species may also be a pathway for residual oil from sediments to vertebrate species that are still impacted (e.g. have elevated levels of P450 or show negative effects on their populations). Hydrocarbon (TPAH) concentrations in littorine snails, prey of harlequin ducks and black oystercatchers, ranged from 4 to 27 mg/g dry wt. in several 1989 samples [Exxon Valdez Trustee Hydrocarbon Database (EVTHD]. Shigenaka (1997) reported that PAH concentrations in drills and littorines were 1 and 2 orders of magnitude lower respectively than concentrations in mussels at the same site (Smith Island, Prince William Sound in 1990). Concentrations in littorines (*Littorina sitkana* and *L. scutulata*) in 10 mussel beds in the spill area in 1993 were generally not more than 1 order of magnitude lower than concentrations in mussels from the same bed. (Project 99090, unpublished data) Limpets (2 samples) and *Macoma* spp. clams are the only other harlequin prey (other than mussels) that are reported in EVTHD. Prey notably missing from that database are hermit crabs (*Pagurus* spp.), drills (*Nucella* spp.), nemerteans, and annelids, all occasional in the beds we have sampled since 1991. Because crabs, drills, and worms are not filter feeders, they are expected to have lower concentrations of TPAHs than mussels in the same bed, but they could add to the body burden of animals who also prey on mussels or could be a pathway for oil to predators who do not eat mussels. For example, pigeon guillemots, who do not eat mussels, have been observed feeding hermit crabs to their chicks. Masked greenling, a nearshore fish species, was found to have elevated levels of P450 in oiled areas (Holland-Bartels, 1998), but the source of contamination is not clear. In cooperation with restoration project 99375, our project will investigate the link between hydrocarbons in sediment, in closely associated invertebrates, and in nearshore and intertidal fishes.

Clams (*Prototheca, Saxidomus,* and *Macoma* spp.) and cockles (*Clinocardium*) were well sampled soon after the spill by damage assessment studies, but not in recent years (EVTHD). Clams and cockles are common in areas below mussel beds that we have sampled; oil chronically released from mussel bed sediments may impact the communities lower in the intertidal. One *Prototheca* sample we collected in 1993 below a particularly oily mussel bed, contained 4.5 mg/g TPAH, 4 times the mean concentration of mussels in the bed. Otter craters, common below mussel beds sampled since 1991 often had oil sheen in them. Hydrocarbons in clams and cockles may still be affecting predators. *Macoma* spp are consumed by harlequin ducks, who are still listed as Anot recovering@ from the spill; Sea otters and black oystercatchers, Arecovering@ species, consume *Prototheca, Saxidomus,* and *Clinocardium*.

Chemical analysis of samples collected in 1999 will begin in the summer of 1999, but will be completed in fiscal year 2000. Completion of chemical and data analyses is needed to 1) evaluate the effectiveness of mussel bed restoration techniques, 2) evaluate natural recovery rates with respect to modeled rates of recovery 3) examine the degree and pattern of weathering of oil in both restored and untreated beds, 4) assess mussel bed health and 5) examine the hydrocarbon concentrations in other invertebrate fauna in oiled mussel beds to look for links to vertebrate

species that are still impacted. The final report should provide a comprehensive picture of recovery in both restored and naturally recovering mussel beds.

## NEED FOR THE PROJECT

### A. Statement of Problem

Mussels remain an important food source in PWS intertidal communities, particularly for some predators (e.g. harlequin ducks, sea otters, and black oystercatchers) whose recovery is not yet certain. Additionally, mussel beds provide habitat for many other invertebrate species, which are also prey, directly or indirectly, of impacted species. Continued monitoring of hydrocarbons in mussel beds is warranted until this contaminated habitat has fully recovered. Human subsistence users need to know whether mussels and other species trophically linked to the beds are oil free. Untreated mussel beds have not been sampled since 1995, so their hydrocarbon levels are unknown. The patterns of concentration decline from 1991 to 1995, and observations of visible oiling in some mussel beds in early 1997, indicate that many beds have not returned to pre-spill concentrations. Sediment recontamination in half of the restored beds necessitates further monitoring of these beds.

### B. Rationale/ Link to Restoration

Human subsistence harvesters and researchers studying mussel predators need to know if petroleum hydrocarbons still persist in mussel beds. Although the areal extent of contaminated mussel beds is small in proportion to the total area of beds in PWS, the oiled beds are the worst remaining known source of *Exxon Valdez* Oil (EVO) contamination that is biologically available. Other known areas of remaining high contamination are high in the intertidal and armored with asphalt and cobble or boulders (Shigenaka, 1997). Monitoring the gradual return to pre-spill conditions of these beds is basic to all other *Exxon Valdez* Oil Spill (EVOS) studies.

The long term effectiveness of natural recovery and restoration techniques should be assessed to provide guidance in the event of other spills. Oiled beaches remain a problem for PWS residents, prompting this study and other chemical restoration activities.

### C. Location

The mussel beds to be evaluated are in the oil-impacted areas of PWS (Knight Island, Disk Island, Eleanor Island, Chenega Island, Latouche Island, Squirrel Island, and Applegate Island) and two not impacted areas, Olsen Bay in eastern PWS and Drier Bay on Knight Island. Residents of Chenega Bay use the beaches near several of the oiled mussel beds.

## COMMUNITY INVOLVEMENT AND TRADITIONAL ECOLOGICAL KNOWLEDGE

The results will be reported in non-technical terms to the Chenega Bay Village Council in writing, and if the Council so requests, at a public meeting in Chenega Bay as well. Students from the

Youth Area Watch Program, especially those from Chenega Bay will be invited to participate in sampling.

## PROJECT DESIGN

### A. Objectives

1. Measure hydrocarbon concentrations in mussels and underlying sediments, and mussel densities, in beds that were restored in 1994 to evaluate degree of recontamination and to assess mussel bed health. Similar measures will be taken in uncleaned control beds for comparison.

2. Measure the hydrocarbon concentrations in mussels and underlying sediments and mussel densities in untreated mussel beds that remained contaminated with EVO in 1995. Similar measures will be taken in uncleaned control beds for comparison.

3. Measure the hydrocarbon concentrations in selected invertebrate fauna associated with both categories of mussel beds. We will target prey species of vertebrate species still not fully recovered from the spill. (harlequin duck, pigeon guillemot, sea otter, black oystercatcher) and of vertebrate species that may be prey of the impacted species (nearshore forage fish).

### B. Methods

Our working hypotheses are 1) that the beds restored in 1994 have remained clean and intact and 2) that sediment and tissue hydrocarbon concentrations in untreated oiled PWS mussel beds have returned to pre-spill levels. Data to be collected are TPH (sediments) and TPAH (mussels and other invertebrates) concentrations and faunal densities ( e.g. mussels/$m^2$).

### Objective 1

Site Selection

Sites to be sampled in 1999 include those restored in 1994 and adjacent uncleaned beds that represent natural restoration.

Restored Mussel Beds Proposed for sampling in 1999

| Beach Segment* | Geographic Name | Notes |
|---|---|---|
| CH10B-2A | Chenega Island | originally sampled as 2 beds, now as 1 bed with 3 zones |
| CH10B-2B | Chenega Island | |
| CH10B-2C | Chenega Island | |
| CH10B-2D | Chenega Island | uncleaned reference bed |
| DI067A-1 | Disk Island | |
| DI067A-2AL | Disk Island | |
| DI067A-2AR | Disk Island | |

| | | |
|---|---|---|
| DI067A-2B | Disk Island | |
| DI067A-2C | Disk Island | uncleaned reference bed |
| EL011A-B | Eleanor Island | |
| EL011A-C | Eleanor Island | |
| EL011A-D | Eleanor Island | uncleaned reference bed |
| KN113B-2 | Herring Bay | sample 2 depths and up slope area |
| SL001D-2 | Squirrel Island | |

* nomenclature follows the interagency Shoreline Cleanup Assessment Team (SCAT) shoreline assessment segment designations. Where we sampled multiple oiled mussel beds within one segment, they are designated with a number following the segment number.

Sampling

Within each of these beds, triplicate pooled samples of mussels and of sediments will be collected at 8 random spots and placed in hydrocarbon-free glass jars. Approximately 20 mussels, will be collected by hand; the sediments will be collected with a hydrocarbon-free spoon. In 1992, intensive sampling indicated 3 distinct zones of oiling at CH010B-2A (Harris et al. 1996). These zones were obscured when the bed was cleaned, at least to a depth of 12 cm, but the recontamination pattern shown in 1996 samples indicates the re-formation of zones. Therefore, at CH010B-2A the initial zones will be re-sampled, so that triplicate pooled samples will be collected from each zone. At most cleaned beds and at the 3 uncleaned reference beds, sediments will be sampled at 3 depths: surface (0-2 cm), deep (4-6 cm), and below replaced sediment depth (>12 cm) to enable us to determine if oil below the replaced layer has recontaminated surficial sediments. Sediments will be sampled at only two depths, surface and deep, at the Herring Bay restored bed ( KN113B-2) because oiled sediments were removed down to bedrock. In that bed, the recontamination source in 1996 appeared to be oiled sediments up slope of the restored area so the up slope area will be re-sampled.

All samples will be immediately cooled, and frozen within 6 h. Samples will be given a unique number in the field to facilitate sample tracking through chemical and data analysis and inclusion in a restoration hydrocarbon data base. Mussel densities will be estimated by counting mussels in 2 of the 4 frames within a 0.25 m x 0.25 m sampling quadrat in at least 8 subsites along the transect and will be expressed as mussels/m5. In the same 8 quadrats, we will count the number of targeted invertebrates and express densities as species name/$m^2$.

Chemical Analysis

Sediment samples will be analyzed by ultraviolet fluorescence as adapted from Krahn et al.(1991) and used successfully at Auke Bay Laboratory since 1992. Concentrations will be reported in mg total hydrocarbons /g wet weight of sediment (TPH). All mussel, other invertebrate samples, and selected sediments will be analyzed by gas chromatography/mass spectroscopy (GC/MS) for quantitative measurements of individual polynuclear aromatic hydrocarbons (PAH) (Larsen et al., 1992); concentrations will be reported in mg total PAH / g dry weight of mussel or sediment (TPAH). Perylene, which is biogenic, will not be included in TPAH. At least one sediment sample from each bed will be analyzed by GC/MS to examine the degree and pattern of weathering of EVO if TPH levels in that bed are above pre-spill levels (50 mg/g).

Data Analysis

Hydrocarbon data will be tested for normality and log transformed if necessary to carry out ANOVA to examine differences between sites (1999 data) and sampling times at each site (using 1992-1999 data). A longer time series will be possible for some sites where hydrocarbon samples have been collected since the mid 1970's. Assuming triplicate sampling as proposed, statistical power will be 80% (alpha =0.05) to detect a change or difference of 60% at two sites or two sampling times at the same station (Kinetic Laboratories, 1993). Weathering of EVO will be examined using first-order kinetic loss rate modeling (Short and Heintz 1997)
Densities of targeted invertebrates in restored beds will be compared with densities in the appropriate unrestored bed(s).

**Objective 2**

Site Selection:

The 14 oiled mussel beds selected for sampling still contained > 0.09 mg/g TPAH in mussel tissues and/or > 200 mg/g TPH in underlying sediments in 1995. KN004-2 was not sampled in 1995, but was selected because TPAH in mussels was 0.6 mg/g in 1994. Olsen Bay and Barnes Cove, two unoiled reference beds monitored since 1991, will be also be sampled.

Unrestored Mussels Beds Proposed for Sampling in 1999:

| Beach Segment* | Geographic Name | Notes |
|---|---|---|
| AE005A-2 | Applegate Island | |
| CH009A-3 | Chenega Island | |
| DI067A-6 | Disk Island | sampling 2 sediment depths |
| EL013A | Eleanor Island | sampling of 2 zones, 2 sediment depths |
| EL015A | Eleanor Island | |
| EV036A | Evans Island | |
| KN004-2 | Bay of Isles | |
| KN119A | Herring Bay | |
| KN133A-1 | Herring Bay | sampling of 3 zones, 2 sediment depths |
| KN136A-1 | Bay of Isles | |
| KN136A-3 | Bay of Isles | sampling 2 sediment depths |
| KN505A | Herring Point | |
| KN575A | Barnes Cove | unoiled reference |
| LA015E-2 | Latouche Island | sampling 2 sediment depths |
| MA002C | Foul Bay | |
| OLSEN | Olsen Bay | unoiled reference |

Three additional small untreated beds will be sampled, but because these will be sampled similarly to the restored beds they are included under objective 1.

Sampling:

In the untreated beds, mussel and sediment sampling will follow methods developed by this project in previous years (Babcock et al. 1996). In most of the above beds, a transect, generally 30 m long and parallel to the water line (as topography allows), will be established through the

middle of a mussel bed. Triplicate pooled samples of 20-25 mussels each will be collected along the transect and within 1 m above and below the transect and placed in three hydrocarbon (HC)-free jars. Other invertebrates will also be collected along the transect. Three pooled subsamples of surficial sediment (0-2 cm deep) under the mussels will be collected with a HC-free stainless steel spoon into each of three HC-free glass jars. A sample of sediments 4-6 cm below the surface will be taken in five beds where samples at that depth have been collected since 1992 to see if initial patterns of oiling related to depth still persist (see table above).

Two beds, KN133A and EL013B, had zones of significantly different concentrations of oil in 1992 (Harris et al., 1996). These beds will be re-sampled by the zones observed in 1992 (rather than by transect) to see if the initial within-bed oiling pattern persists as concentrations have declined. In each zone, three pooled replicate samples of sediments at depths 0-2 cm, three pooled replicate sediment samples at depths 4-6 cm, and three pooled replicate samples of mussels will be collected. Targeted invertebrates will be collected over the whole bed; replicate samples will be collected if density permits. Sample handing, chemical analysis, and data analysis will follow the procedures discussed under objective 1.

Chemical and Data Analysis

Chemical analysis of samples and data analysis will follow methods described for objective 1.

**Objective 3.**

Site Selection

Selected invertebrates will be collected in all beds sampled under objectives 1 and 2.

Sampling

Invertebrate groups selected for collection are littorines, drills, limpets, chitons, annelids, nemerteans, hermit crabs, clams, and cockles. The latter two groups will be collected below (lower in the intertidal) mussel beds; others will be collected in the bed. Observations in the mussel beds since 1991 indicate that distribution of these select invertebrates is patchy and densities are low, so no specific sampling protocol is proposed; samples will probably have to be collected throughout the bed or the intertidal area below the bed to obtain enough for a tissue sample ( 5 g) of each species. When densities permit, replicate samples of each species will be collected. Samples will be placed in HC-free glass jars and handled as mussel samples are.

Chemical and Data Analysis

Methods follow those for mussel tissue, except that littorines will not be dissected from their shells. A subset of littorines will be dissected and dried to determine the relationship between littorine tissue dry weight and littorine whole body dry weight, so that hydrocarbon concentrations in littorines may be compared with that in mussels and other animals in which just the tissue is analyzed.

Summary of Sampling and Analytical Methods

| Sample Type | Objective 1 Restored Beds | Objective 2 Unrestored Beds | Objective 3 Other Invertebrates | Totals |
|---|---|---|---|---|
| UV Sediment | 141 | 78 | | 219 |

| | | | | |
|---|---|---|---|---|
| GC/MS | | | | |
| Sediment* | 6 | 13 | | (19) |
| Targeted invertebrates+ | | | 20 | 20 |
| Mussels | 48 | 51 | | 99 |
| | | | | 338 |

* Sediments to be analyzed by GC/MS are subsamples of UV sediment samples and therefore do not affect sample totals for each objective. The maximum number of sediments to be analyzed by GC/MS is 19. Sediments will not be analyzed by GC/MS if TPH concentrations are not above pre-spill levels in a bed.

+ maximum number of samples to be collected is estimated at 20, depending on the abundance of selected species

### C. Cooperating Agencies, Contracts, and Other Agency Assistance

We will share a sampling platform in 1999 with Restoration Project 99379, Assessment of Risk to Residual Exxon Valdez Oil in PWS Using P450 Activity in Fishes. We will also suggest sample sites to ensure sampling coordination with that project so that we may be able to support that project with apprropriate chemical data. The only contracts involved will be contract labor for chemical sample processing.

## SCHEDULE

### A. Measurable Project Tasks for FY 2000 (October 1, 1999 - September 30, 2000)

| | |
|---|---|
| Jun.-Sept. FY99 | initiate hydrocarbon analyses (60% complete by Sept.30) |
| Oct. - Dec. | complete hydrocarbon analyses |
| Dec.-Jan. | data analysis |
| Jan. | EVOS workshop |
| April | final report |
| May-Sept. | publication preparation |

### B. Project Milestones and Endpoints

Data analysis and reporting for samples collected in summer of 1999 will be completed in winter 2000, submission of an final report in April of 2000, and preparation of a more public final report or presentation.

### C. Completion Date

If our working hypotheses are shown true (significant amounts of oil are *not* found in PWS mussel beds), our objectives will have been met in April of 2000. If the hypotheses prove false, and significant amounts of oil *are* found, another round of sampling will be proposed probably in 2002.

## PUBLICATIONS AND REPORTS

FY99: none
FY00: final reports ( one to the EVOS trustees, one for the general public) and 2 manuscripts; Effectiveness of Manual Restoration of Oiled Mussel beds, Natural Recovery of Mussel beds Impacted by EVO.

## PROFESSIONAL CONFERENCES

FY00: EVOS workshop

## NORMAL AGENCY MANAGEMENT

NOAA/NMFS has statutory stewardship for most living marine resources; however, if the oil spill had not occurred, NOAA would not be conducting this project. NOAA/NMFS proposes to make a significant contribution (as stated in the proposed budget) to the operation of this project, making it truly cooperative.

## COORDINATION AND INTEGRATION OF RESTORATION EFFORT

Logistics of sampling in 1999 will be tied as closely as practical to the sampling efforts of the Pristane Monitoring project. The potential for overlap is great since the same personnel will be involved. Data and results will be shared with other projects, project 99379 (as discussed) and projects involving mussel predators (Nearshore Vertebrate Predators 99025, Alaska Predator Ecosystem Experiment (99163), and Differentiation/Interchange of Harlequins. Students from the Youth Area Watch (99210) will be invited to participate in sampling. Cooperative efforts in 2000 will largely be data sharing and will result in synthesis of information from other projects, particularly those focusing on predators of mussels and other musel bed invertebrates.

## PROPOSED PRINCIPAL INVESTIGATORS

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**PRINCIPAL INVESTIGATORS**

**Patricia M. Harris**

Education:
New York University
University of Alaska Fairbanks; B.S. Biological Science 1966
Graduate courses at U of A Fairbanks, U of A Southeast, University of British Columbia, U. of Washington

:
Patricia Harris has been involved in *Exxon Valdez* Oil Spill research since March 1989; as a co-principal investigator for NRDA project Subtidal 3, Mussel bed monitoring and restoration (R103-99090), and Pristane monitoring in mussels ( 96195-99195), she has been r esponsible for study design, field logistics, sample collection and assisted in data analysis and proposal and report preparation. She has also assisted sampling for Near shore Vertebrate Predator Project (96025) and Chenega Cleanup project (97291, 98291).

Relevant publications: Co-author of annual and final reports for NRDA study Subtidal 3 and restoration project Monitoring of Oiled Mussel beds, contributing author to annual reports for Pristane Monitoring project, author of several publications pertaining to distribution of Exxon Valdez oil in mussels and underlying sediments. Several public presentations of oil-related scientific research.

Responsibilities: Study design, sample collection logistics, collect hydrocarbon samples, analyze data, prepare proposals and reports.

**Christine C. Brodersen**

Education:
University of Washington; B.S. Zoology 1971
Graduate work at U of A Southeast

Relevant Experience:
1974 - present: Fisheries Research Biologist at Auke Bay Fisheries Laboratory, including:

1974 - mid-1980s: Conducted laboratory research on the toxicity of Alaskan crude oils to Alaskan marine species, especially larval stages.
1989 - 1991: Conducted training classes in the handling of hydrocarbon-analysis samples for personnel in agencies doing EVOS field work; coordinated legal chain-of-custody procedures for Auke Bay Laboratory EVOS work.

1989 - present: Participated in proposals, data analysis and reporting for mussel bed monitoring and restoration work (R103 - 96090) and conducted associated laboratory experiments on measures of potentially oil-related stress in mussels.

1994 - 1996; Conducted laboratory experiments on trophic transfer of pristane that helped establish the theories behind the PWS pristane project (96195).

1996: Participated in extensive mussel population surveys in PWS with Nearshore Vertebrate Predator study.

1997 & 1998: Principal investigator of the oil and biology monitoring portion of the Chenega Shoreline Restoration project (97291, 98291).

Relevant publications & presentations:
More than a dozen papers, reports and presentations on the effects of Alaskan oil, tanker ballast water, and the EVOS.
Responsibilities: Analyze data, prepare proposals, track samples, and collect hydrocarbon samples.

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